RELATIVE BENEFIT ASSESSMENT OF FIRE PROTECTION SYSTEM CHANGES

Ginger Bennett
Booz-Allen & Hamilton, Inc.
Dayton, OH 45431 **USA**

ABSTRACT

With the rapidly expanding variety of fire protection technologies competing for limited R&D budgets. facilities, and expertise, it has become necessary to develop a system benefit assessment methodology for use in RXD efforts. Such a methodology is necessary to compare. rate. and **evaluate** these competing technologies in order to select the most promising for further development, to assess the potential benefits and costs for each. and to develop a rational developmental funding profile for each technology and an overall R&D program as a whole. The purpose **of** this discussion will be **to** present recent findings and to discuss future efforts.

BACKGROUND

Aircraft Fire Hazards

Aircraft have special problems in regard to fires. Aircraft carry munitions that can be initiated by a fire. In addition. aircraft also contain large quantities of fuel distributed in fuel tanks throughout the aircraft with fuel lines running between these tanks and the engine(s). These facts contribute to three basic types of aircraft fire zones—dry bays. engine nacelles, and fuel tank ullage.

Fire-extinguishing systems are used on military and commercial aircraft to protect engine nacelles (the region surrounding the exterior of the jet engine case and shrouded by an outer cover, and typically ventilated), dry bays (which can include wing leading/trailing edges. landing gear, avionics. and weapons bays), and fuel tanks (*as* an inertant in the fuel tank ullage). These systems are fixed in configuration and activated remotely to totally flood the compartment in question with fire extinguishant. Auxiliary power units (APU), which provide ground, supplementary, or emergency power. are also frequently protected using such systems, either as stand-alone units or in conjunction with the engine nacelle fire-extinguishing system.

Fire is either the primary cause or a contributing factor in most cases of loss of aircraft assets. In many instances, injuries to personnel and loss of mission capability accompany a fire event. Aircraft fires are *a* significant cost to the Air Force. Methods and technologies to mitigate them or "design them out" are imperative, not only to save aircraft, but also to save lives and prevent property damage.

Aircraft Dry Bays

Dry bays are defined as void volumes within the mold line of the aircraft, excluding air inlets, engine compartments, and exhaust nozzles. Examples include wing leading edge bays, landing gear wheel wells, avionics equipment bays. and weapons bays. Dry bays can include wing leading/trailing edges, landing gear, avionics and weapons bays. and related zones where a catastrophic rupture of flammable fluid and an ignition supply. such as from a ballistic impact. can create a sustained fire. Dry bays frequently contain fluid lines (fuel, hydraulic, coolant), bleed air ducts, and electrical cables and may contain avionics, flight control actuators. hydraulic accumulators. and liquid oxygen dewars.

Aircraft Engine Nacelles/Auxiliary Power Units (APU)

The engine nacelle is defined as the region surrounding the exterior of the jet engine case, shrouded by an outer cover, and typically ventilated. Auxiliary power units (APU) are machinery units that provide supplemental, auxiliary, or emergency power to all or some subsystems of the aircraft.

Engine nacelle fire protection systems are designed to protect against events such as ruptured or leaking fuel. hydraulic fluid, or oil lines within the nacelle. In these circumstances, flammable fluids can leak onto the hot engine case or accessory components and ignite. These systems can also protect against the results of catastrophic events such as thrown turbine blades, which can instantaneously rupture fuel sources or overheating components and initiate fluid fire scenarios. The first step in such cases is to shut down the engine. once the proximity fire detector confirms a fire is present, and the pilot is satisfied that a true fire event has occurred. Even with the engine shut down and flammable fluid supply turned off, up to a minute or more of fuel and other flammable fluids flowing into the fire zone can occur, sometimes under high-pressure, depending upon the location and nature of the failure and the capability to remotely arrest the flow near the point of damage. Under these conditions, a supply of fuel can be maintained for a lengthy period to create robust fire conditions that, left unchecked, can heat and ignite severe metal fires or burn through surrounding structure and threaten the welfare of the aircraft, creating fire conditions in collateral areas before the fuel is drained. thereby weakening key structures. In addition, impacts into the engine nacelle by ballistic projectiles in combat can also create failure conditions and resultant fires (provided that the engine case is not penetrated, which could result in catastrophic engine failure becoming the more immediate threat).

APUs are used to provide supplemental, auxiliary, or emergency power to all or some of the subsystems of the aircraft, either on the ground or in flight. These units function and generate power independently from the normal aircraft engine systems. The power units may be miniature turbines or other power generating equipment, but are typically smaller than the normal jet engine propulsion systems. These compartments must be protected against potential fires. since the possibility of fuel. hydraulic fluid, or oil leakage onto the hot power unit and equipment or catastrophic unit failure can create fire scenarios just as in the engine nacelles. For many military aircraft, the engine fire protection system is plumbed to be alternatively used in the auxiliary power unit compartment, since in most cases the engine fire protection system's capacity is more than adequate for the smaller volume of the APU bay. In some cases, however, the APU compartment may have a larger free volume than an individual engine nacelle or otherwise require a greater quantity of extinguishant than the nacelle, so great care must be taken to assure that sufficient capacity is designed for either use. APU compartments can be ventilated, so provision must be made for dilution of extinguishant by ventilation airflow during discharge. In many cases, however, the ventilation system is designed to be closed during discharge, hopefully sealing off the compartment. For many military transport and most commercial aircraft, an independent fire protection system is designed for a remote APU compartment, which may be located within the cabin or cargo section, or in the tail section. These systems must then be designed separately from engine nacelle systems.

Aircraft Fuel Tanks

Historically, fuel fire and explosion are a major cause of aircraft losses in combat. Data from Southeast Asia show over half of the aircraft combat losses involved fuel fires and explosions.

While other factors might also have contributed to the loss (e.g., pilot killed. loss of control. etc.), this fact nonetheless indicates the fuel system is a very significant contributor to an aircraft's vulnerability. Therefore, to increase survivability. various techniques are used to reduce the vulnerability of the fuel system to this significant threat effect.

Ullage (the void space above the fuel level in *a* fuel tank) in aircraft fuel tanks can have a potentially explosive fuel-air mixture. If initiated by a combat threat, an explosion can result. Halon 1301 is used to inert these fuel tanks and prevent this phenomenon from occurring. Currently, two **USAF** aircraft systems use halon for fuel tank inerting: F-16 and F-117.

Fuel tank explosions are a result of ullage deflagrations or detonations where the combustion overpressure generated exceeds the structural strength of the tank. With large ignition sources, combustion will occur and overpressures will vary according to the threat level, tank volume, and oxygen concentration. If the combustion wave propagates throughout the ullage with near stoichiometric fuel/air mixture. a pressure increase of over 100 psig (8 times atmospheric pressure) is theoretically possible. The inerting system must provide protection from in-tank arcing due to lightning, electrostatic discharge, and combat threats [1].

Halon Replacement

International concern for the apparent depletion of stratospheric ozone has led to agreement to eliminate man-made production of ozone-depleting chemicals (ODC). Recent studies have shown halons are the worst known ODC per unit mass making it the first chemical family to be eliminated. Originally planned to be phased out of production by the year 2000, the production of halon was accelerated to January 1994. This now leaves only existing stocks of halon for use in essential applications such as aircraft fire and explosion systems.

The banning of halon production and the search for non-halon fire extinguishing material has resulted in **a** rapid evolution of a wide variety of aircraft fire protection technologies. This has produced sizable development programs by government, university, industry. and R&D organizations. These are expected to continue for some time. especially with the advent of the DoD 9-year Next Generation Fire Protection Technology Program (NGP).

Because of the heavy reliance on halon in the past. halon's high effectiveness. and the "standardized" approach to the design and test of halon systems. there has been little or no development of methodologies for evaluating the various competing fire extinguishing technologies that may replace halon.

With the current explosion of fire protection technologies competing for limited R&D budgets, facilities, and expertise, it has become necessary to develop an R&D assessment methodology to compare, rate. and evaluate these competing technologies in order to select the most promising for further R&D, to assess the potential benefits and costs for each, and to develop a rational funding profile for each technology and the R&D program as a whole.

This project will develop from an understanding of the fire protection state-of-the-art to en assessment of modifying individual components to an identification and quantification of cost drivers. and finally culminate in **a** tool with established baselines. This tool will be usable not only in its current form, but also as a foundation for a more comprehensive methodology capable of evolving with the fire protection state-of-the-art.

OBJECTIVE

The primary goal of this program is to develop means to evaluate the relative desirability of potential changes to current fire protection systems and/or procedures that would enhance fire suppression efficiency. Each stage is designed to be a logical progression to reach this objective. The end-goal of this project is to apply the methodology as soon as possible during the technology development process to make sure the technology will be retrofitable and superior to currently available solutions.

OVERVIEW OF PROGRAM

The project comprises several phases. Phase I will determine the positive and negative features of the current technologies and practices as uncovered under Project I.a. and divide each system into components including, but not limited to the extinguishing agent, storage bottle, distribution plumbing, and human operator for nonautomatic systems. Phase II will identify all the potential impacts and interdependencies resulting from modifications to a given component (e.g., hardware, agent) as well as procedural changes. Phase III will identify the cost drivers for making modifications to fire protection systems as they impact development. acquisition, certification, and deployment; rank these cost drivers in order of magnitude and determine which cost drivers to carry forward; and quantify both the recurring and nonrecumng cost drivers. Phase IV will entail assembling the complete life cycle cost methodology using Expert Choice, an analytical hierarchy process software tool; assessing the risks of formulating conclusions when comparing dissimilar technologies when presented with incomplete data, etc.; developing baselines using the previously identified near-term solutions, (HFC-125, HFC-227ea, etc.); and identifying technology areas with a potential for high payoff for immediate exploitation.

PLATFORMS UNDER CONSIDERATION

This task will examine several weapon systems of the different services, including the following: US Air Force (F-18, F-16, C-17, C-130, Blackhawk helicopter, and Chinook helicopter); US Navy (DDG51 [Arleigh Burke] Class — AEGIS Guided Missile Destroyer, LHD1 [WASP]/LHA1 [TARAWA] Class — Amphibious Helo/Landing Craft Carriers; and LCAC — Landing Craft Air Cushion); and US Army (MI Tank Series, M2, M3 Bradley Personnel Carrier, and M992 FAASV Ammunition Resupply Vehicle). Originally, Command and Control Centers were to be investigated; however, they were eventually omitted from this study.

CURRENT WORK

The current work encompasses the analysis of current configurations. the identification and ranking of cost drivers, and the acquisition of data for models (Expert Choice, Air Force Materiel Command Logistics Support Cost [LSC] model, Operational Requirements-based Casualty Assessment [ORCA] model, and the BLUEMAX model).

Analysis of Current Configurations

The positive and negative features of the current technologies, possible areas for modification, and practices as uncovered under the DoD 9-year Next Generation Fire Protection Technology

Program (NGP) Element 1.a., “Development of Model Fires from DoD Fire Data,” have been determined (due to the recent completion of this effort). This information is being reviewed and compiled into a usable format. The system information is being broken down into components including, but not inclusive to the agent, storage bottle, distribution plumbing, and human operator for non-automatic systems. Since the goal of the NGP is *a* retrofitable technology. it is not anticipated there will be any extreme deviations from the types of components found in current systems and practices. A timeline is being derived for each platform under consideration beginning with the estimated fire initiation, detection, extinguishant discharge. and transport times. The following criteria are being employed when evaluating the method of fire suppression to be employed: technology and performance characteristics, R&D lab and small-scale testing required, R&D medium to large-scale testing required, suppression effectiveness (theoretical and design). and certification method.

Task Status

The purpose of NGP Element 1.a., “Development of Model Fires from DoD Fire Data.” was to characterize the fires encountered; derive a few model fires to guide NGP research; and identify Halon 1301 system constraints to guide NGP research. Many factors can have a dramatic effect on fire intensity and suppression results. Some of these include fuel type, flow type and rate. and droplet size. The intent of this task was to characterize and tabulate the nature. frequency, consequences (including personnel injuries), and severity of fires previously and currently attacked using Halon 1301. This involved determining the fuel flow characteristics during such fires and their impact on suppressant requirements. A small set of representative (model) fires for other elements in the Program was constructed. Development of appropriate new technologies requires knowledge of the fires of concern and the characteristics and limitations of the systems they will replace or into which they will be retrofitted. The descriptions of the environments of **the** current systems compiled during this program will serve as boundary conditions for the new technologies to be developed in subsequent elements of the NGP Program.

The items queried from the aircraft community (System Program Offices and airframers) as well as some generic responses (*so* as not to reveal specific weapon system platform infomation) are given below. Generic information requested included the number of aircraft, service cycle refill (years). fire types (pool fires, mist...), and estimated halon use/year/aircraft. Information (number of fire zones, size, volume, free volume, operating conditions, etc.) regarding the fire zone was also queried. The fire zone may be defined as compartments containing flammable materials or flammable fluid lines or tanks, if such compartments ***also*** contain sources of ignition [2].

The existing extinguishant information was also of interest. This information included type, number of systems, extinguisher trigger mode (automatic or pilot activated [manual]).extinguisher volume (in’), size of extinguishant container (in, in, in). storage compartment for extinguishant bottle (in, in, in), free volume in storage compartment (ft^3), normal charge and pressure of extinguisher container (psi), maximum extinguisher container pressure (psi), extinguisher container percent filled (%), extinguisher container orientation (upright with valves at bottom. etc.), extinguisher container weight without halon (lb), halon wt (lb), extinguisher container location (inside/outside fire zone). strategy for use (detect fire. select bottle, select engine, pull “T” handle), number of shots, suppression success fraction (based on historical data, i.e., combat and peacetime data), extinguisher system manufacturer. type and degree of restriction on the use of alternative fluids. and range of expected operating temperatures for the bottle and the plumbing (°F).

An item, which presents an opportunity for redesign with the advent of new extinguishants, is the distribution system. Therefore, the following information was requested to obtain specific information on this system: extinguisher dispersion method, extinguisher discharge rate (CFM), distribution system plumbing, inner diameter (in), length (in), shape (bends, elbows) (system complexity), number and nature of nozzles/pipe terminations, access of current distribution plumbing for retrofit, access and available space for additional distribution plumbing or nozzle modification, and evidence of halon distribution characteristics (from certification tests).

The optimization of the fire suppression delivery system is imperative in making retrofitable technologies that can meet the requirements of the weapon systems. Extensive DoD efforts to identify optimal near-term halon alternative technologies have shown that, even if available, currently tested alternatives have sizable (2-3X) weight and volume penalties. Their application to fielded weapon systems (whose service lives are being extended) could require expending large amounts of funding and time for system redesign and reconfiguration at a time of defense budget reductions and downsizing. Experiments (such as recent F/A-18E/F tests. which have allowed comparable amounts of HFC-125 to be used to replace the Halon 1301 system) have shown that significantly enhanced agent dispersion can result from improvements in the suppressant delivery system [3].

The effect of making modifications to agent distribution systems may significantly impact how less effective agents may be utilized. The impact of this retrofit is one of the items being evaluated in this current effort. The effect of access to the distribution system and bottles is also important. This may temper the ability to retrofit the aircraft due to the incurred costs of modifying the aircraft. Due to the less efficient agents, more bottles or larger bottles may be necessary. This survey queried the community for the specific platforms on their ability to accommodate more bottles or larger bottles. The costs of retrofitting a current aircraft design to incorporate a different distribution system or the addition or enlargement of the agent bottles, may incur significant costs. This may not be possible and/or may not be preferred.

Identification and Ranking of Cost Drivers

Cost drivers for making modifications to fire protection systems as they impact development, acquisition, certification, and deployment—in essence the costs to field the modifications—are being identified. These cost drivers are being ranked in order of magnitude. The panel members will determine which cost drivers to carry forward into the Cost Driver Quantification stage. When identifying cost drivers, the following assessments are being performed: Technical Assessment, Cost Assessment, Time Assessment, and Risk Assessment.

Task Status

Specific cost information (development, certification, deployment, operating and support, etc.) has been difficult information to obtain. Most contacts report that this type of information is not readily accessible and therefore difficult to compile. To date, one method to obtain cost information that is compiled in a centralized database is to contact the Air Force Materiel Command (HQ AFMC). They manage a database called the Weapon System Cost Retrieval System (WSCRS). This database is sorted by National Stock Number (NSN). If the NSNs are known for the fire suppression system components, these can be tracked in the system and the cost information (procurement and repair) can be found. Points of Contact have been obtained in all three services for similar organizations such as the one in HQ AFMC. These NSNs are being requested from the Equipment Specialists of the Air Logistics Centers (ALC) (or the Service Equivalent). If this information is not within the ALC, the System Program Office (SPO) or potentially the airframer may need to be contacted (especially for cost information on the distribution systems). This was a breakthrough in obtaining cost information for the various components. Other cost information such as the modification costs will need to be obtained from the responsible organizations (SPO).

Acquisition of Data for Models

To assist in developing the methodology and baselines, several existing models are being considered. Prior to their requisite use. data pertinent to the operation of these models in subsequent stages of this program are being compiled. A brief description of the models to be used follows.

Expert Choice

Expert Choice is a commercial-off-the-shelf (COTS) decision support software package that can be used for strategic planning, program analysis, and optimizing resource allocation. It is a multicriteria decision support software tool that uses the analytic hierarchy process (AHP) as the decision making methodology. AHP arranges the components of a problem into an hierarchical structure similar to a family tree. Complex decisions are decomposed into a series of simple comparisons and rankings, and a decision is synthesized from these results. This structure allows the decision making process to be thoroughly documented for future reference. Multiple objectives, alternatives, and criteria can be defined by the user. Expert Choice can integrate subjective judgments with numerical data in developing the decision model. Sensitivity analysis capabilities are provided in order to investigate the relative importance of various assumptions or the impact of various alternatives.

Air Force Materiel Command Logistics Support Cost (LSC) Model

Life-cycle costs of fire suppression technologies can be addressed using various cost models such as the Air Force Materiel Command Logistics Support Cost (LSC) Model. The development of a replacement aircraft fire-extinguishing technology will generate a requirement for the weapon system program directors to address life-cycle costs. Life-cycle costs include all the costs associated with a vehicle or subsystem over its useful lifetime, including its purchase price. For an aircraft fire suppression system, these costs include maintenance manpower, consumable agents, parts. retrofit costs. training, development. depot maintenance, support equipment, flight qualification. and initial production. Determining retrofit costs is also required for DoD budget inputs. AFR 173-13 requires that a cost analysis be performed for all modifications that affect the life cycle cost of the system being modified or that will affect the operating and support costs to any appropriation over the expected remaining system service life.

Operational Requirements-Based Casualty Assessment (ORCA) Software System

The Operational Requirements-based Casualty Assessment (ORCA) model translates data on the toxicity and compatibility of new suppressants with humans and their principal degradation products to the ability of personnel to perform their key functions and the subsequent impact on platform overall mission effectiveness. A methodology is being developed using compatibility data for the existing fire suppression technologies (HFC-125. dry chemicals. aerosols, water mist. etc.) as a starting point until the new fire technologies and their corresponding compatibility data are identified. Probabilistic scenarios will be generated for the applicable weapon systems as well as for maintenance personnel exposed to an agent, using the interaction of the agent and its decomposition with humans. As the compatibility data for the new suppressants are made available during the NGP program, they would be implemented into the ORCA model and similar analyses would be performed as with the existing agents. One product of this proposed project is the determination of acceptable exposure levels for different missions and operating conditions, which can accommodate personnel evacuation or length of exposure. This will establish the upper permissible concentration thresholds in which the suppressants must demonstrate successful fire-extinguishing performance.

BLUEMAX

Particular to the NGP program will be the use of BLUEMAX to estimate the cost of the additional fuel consumption caused by the weight of the fire suppression system on an aircraft as well as the weight scale-up factor reflecting the additional hardware that must be included because of the fire suppression system, e.g., mounting brackets, fasteners, tubing, etc.

Task Status

Expert Choice and Air Force Materiel Command Logistics Support Cost (LSC) Model

The identification of cost information necessary to access the total costs associated with combat vehicle fire-extinguishing systems has been completed. At the weapon system level these costs include systems certification, toxicity, test equipment, certification methodology, maintenance, support, manufacturing, and logistics. This information will be used in the LSC and Expert Choice models. The following discussion describes the components that comprise the various cost elements. The lists below are not exhaustive ones.

(a) Items that affect maintenance costs — unscheduled servicing, time change (item. frequency, hours), test equipment, deployment gear, HazMat gear, special storage site costs, special transportation equipment costs. initial spares and repair parts, crew size, mean time to repair, mean time between failure, number of programmed flying/operating hours, peculiar support equipment, usage rate, costs of items within system, repair level probability (base or depot), weight, shipping costs, packing costs, cleanup procedures and equipment, special handling equipment, disposal costs, servicing equipment and expectant life, corrosion, inspections, skill levels, and consumable items (sealants, gaskets, safety wire, etc.).

(b) Factors that may affect acquisition costs — system engineering/program management, configuration control, technical data, TOs, modification of weapon system, human factors design considerations, spares support, NDI methods. repair tools, repair techniques/development of battle damage, safety of flight issues, software support, tolerances, initial tooling, modification strategy, legal costs, weapon crew, emergency procedures, etc.

(c) Items that affect operation and support costs — fuel penalty, special logistics (shipping containers, special trailers, new storage facilities) packaging protection levels, airlift requirements, highway standards, safety, fragile, sensitive, or hazardous material requirements, clarify mobility, deployability, and transportability requirements, requirements for special permits, equipment performance, mobility, transportability, service life, and user operational test and evaluation, transportability criteria, etc.

(d) Factors that may affect engineering and manufacturing development costs — prime mission equipment (structure, integration, assembly, test and checkout, propulsion, installed equipment (hardware/software), system and application software (where applicable), system test and evaluation, system engineering/program management (flyaway cost), support equipment (peculiar and common), training, data. initial spares and repair parts, operational/site activation. industrial facilities, in-house. contingency/risk factor, etc. Other cost items include performance of Trades Studies, acquisition of SAF/AQ halon waivers. disposal costs, etc.

ORCA

The latest version of ORCA has been compiled and linked. The required data format needed for the toxicity input file have been requested from the Army Research Laboratory.

The following arc scveral DoD applications for the ORCA model:

(a) Armored vehicles have total-flood fire extinguishing systems in them. If **a** fire occurs and the extinguishing system is activated, crewmembers are exposed to the clean agent. the byproducts of combustion, the clean agent plus the byproducts of combustion, and the decomposition of the new agent in the fire environment. The crew needs to be able to either continue performing the mission. or discontinue the mission entirely and drive the vehicle away or at least be able to evacuate. These individuals could be exposed to fire (resulting in burns), obscuration of the eyes due to the nature of the extinguishant (dry powder. particulate [mist, fog]), toxic gases, particulates that could get into the lungs and effect breathing, cardiac sensitizers, disorientation, impeded decision making ability, degraded visibility, just to mention a few examples. ORCA could be used to evaluate these insults and their effects on the individual's ability to escape or continue to perform his mission.

(b) Helicopters have portable Halon 1301 extinguishers for use in the cabin and engine fire extinguishing systems. Fixed engine systems could also allow extinguishant to bleed into the cabin space due to its close proximity. The effects of the agent and its decomposition would need to be evaluated due to the peak performance required for helicopter control.

(c) Cargo hays, such as the **C-SA** cargo bay. have a total-flood extinguishing systems. Often therc are crewmembers in this area who would experience exposure to the agent and its decomposition.

(d) The Navy has total-flood systems in the engine and machine rooms onboard ships. The effects of the decomposed agent and its mixing with the byproducts of the fire would affect the engine room operators and subsequent firefighters sent in to verify the extinguishment.

(e) Maintenance personnel could be exposed particularly to the clean agent, during its installation, replacemcnt, demilitarization, banking. recycling, and destruction.

BLUEMAX

Efforts are underway to obtain the aircraft data files for BLUEMAX for the C-17 and F/A-18. The aircraft scenario files for the F-16 and C-I 30 have been restored and tested. BLUEMAX is only valid for fixed wing aircraft, therefore, no BLUEMAX data for the H-60 and CH-47 will be obtained.

FUTURE WORK

Future work will encompass the identification of potential impacts resulting from modifications, the quantification of cost drivers. and the formulation of a methodology and devclopment of baselines.

Identification of Potential Impacts Resulting from Modifications

The potential impacts resulting from modifications to a given component (e.g., hardware, agent) as well as procedural changes will be identified. For instance, given a change in agent, what will be the impact(s) to field the system? Special attention will be given to the interdependency of various components (e.g., agent efficiency, plumbing diameter, etc.). For instance, a less efficient agent may be able to use existing plumbing but require a larger bottle; however, to discharge the contents of a larger volume in the required time, larger diameter distribution tubes may be required. The potential impacts will be determined and potential interactions identified.

Quantification of Cost Drivers

This task will involve the quantification of both the recurring and nonrecurring cost drivers. Recurring costs, e.g., maintenance, weight, will be tied to operational hours. System improvements will appear as decreases in operational costs per hour and detriments will appear as increases in operational costs. Nonrecurring costs include initial acquisition, retrofit, etc.

Methodology Formulation and Development of Baselines

This will entail assembling the complete life cycle cost methodology using Expert Choice, an analytical hierarchy process software tool; assessing the risks of formulating conclusions when comparing dissimilar technologies when presented with incomplete data, etc.; developing baselines using the previously identified near-term solutions, (HFC-I25, HFC-227ea, etc.); and identifying technology areas with a potential for high payoff for immediate exploitation.

The baselines developed in this phase will be important to the application of methodology, but, they will not be made integral. By keeping the baselines distinct from the methodology, new baselines can be easily established in the future as fire protection technologies evolve. **These** baselines will offer a goal that emerging technologies must surpass at a given stage prior to proceeding further. This will help assure that NGP achieves its goal of replacing existing halon installations with minimum impact on the weapon systems.

SUMMARY

Extensive DoD efforts to identify optimal near-term halon alternative technologies have shown that, even if available, currently tested alternatives have sizable (2-3X) weight and volume penalties. Their application to fielded weapon systems (whose service lives are being extended) could require expending large amounts of funding and time for system redesign and reconfiguration at a time of defense budget reductions and downsizing. The optimization of the fire suppression system is imperative in making retrofitable technologies that can meet the requirements of the weapon systems.

The outcome of this effort is a methodology for, and execution of, life-cycle cost assessments of Halon 1301 replacement technologies relative to the current best available options, so that platform managers can compare unlike alternatives and make the best selection for their purpose.

ACKNOWLEDGMENTS

The author would like to acknowledge the Air Force Research Laboratory Safety and Survivability Branch, Air Force Materiel Command, C-17, C-130. and F-16 SPOs, Naval Aviation Systems, **Naval** Sea Systems Command. Army Research Laboratory, US Army Tank-Automotive and Armaments Command, and San Antonio Air Logistics Center for their assistance in obtaining the requisite information. It is realized that this information has been difficult to obtain and your efforts are appreciated.

REFERENCES

1. *Fires Experienced and Halon 1301 Suppression Systems in Current Weapon Systems Platforms*, SURVIAC-TR-99-XX, Mar. 1999 (in press).
2. *Extinguishing System*, Fire, *Aircraft, High-Rate-Discharge Type, Installation and Test of*, MIL-E-22285, 7 May 1997 (Approved for public release; distribution is unlimited).
3. "Statement of Need for FY2000 Next Generation Fire Suppression Technology Program (NGP) New Starts," NGP Website (http://www.dtic.mil/ngp/).